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(54) Abstract Title

Method of altering a neighbour cell list in a cellular communication system

(57) Each cell of a cellular communication system has a neighbour list containing the identities of neighbouring cells suitable for handover. Mobile stations in a serving cell scan to detect the identities and signal strengths of other cells and report the results to the serving cell base station. Other cells which are detected but are not on the neighbour list are added to the list while any cells which are on the list but not detected are deleted from the list. Statistical sampling of a large number of reports is used to accurately determine a neighbour list. Cells may be added or deleted from the list depending on the rate or number of times they are detected. The signal strength of the detected cells can be used to rank the cells so that addition or deletion from the neighbour list only occurs if the detected cell is ranked in a predetermined position or range of positions. A combination of detection rate and signal strength ranking can be used as criteria for adding or deleting from the list.

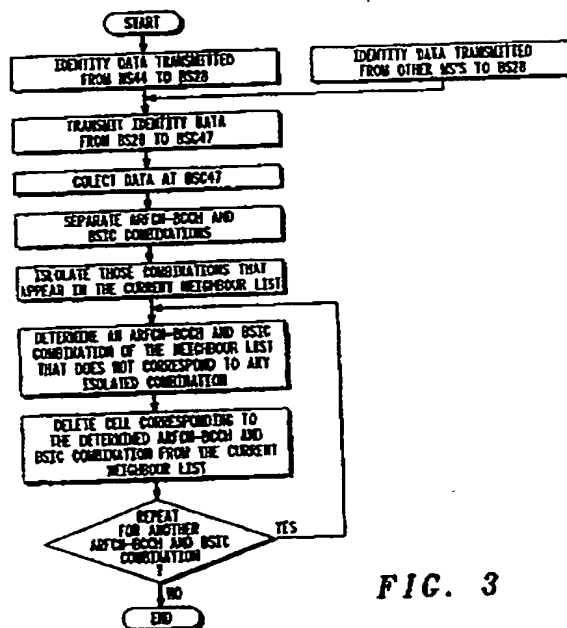


FIG. 3

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

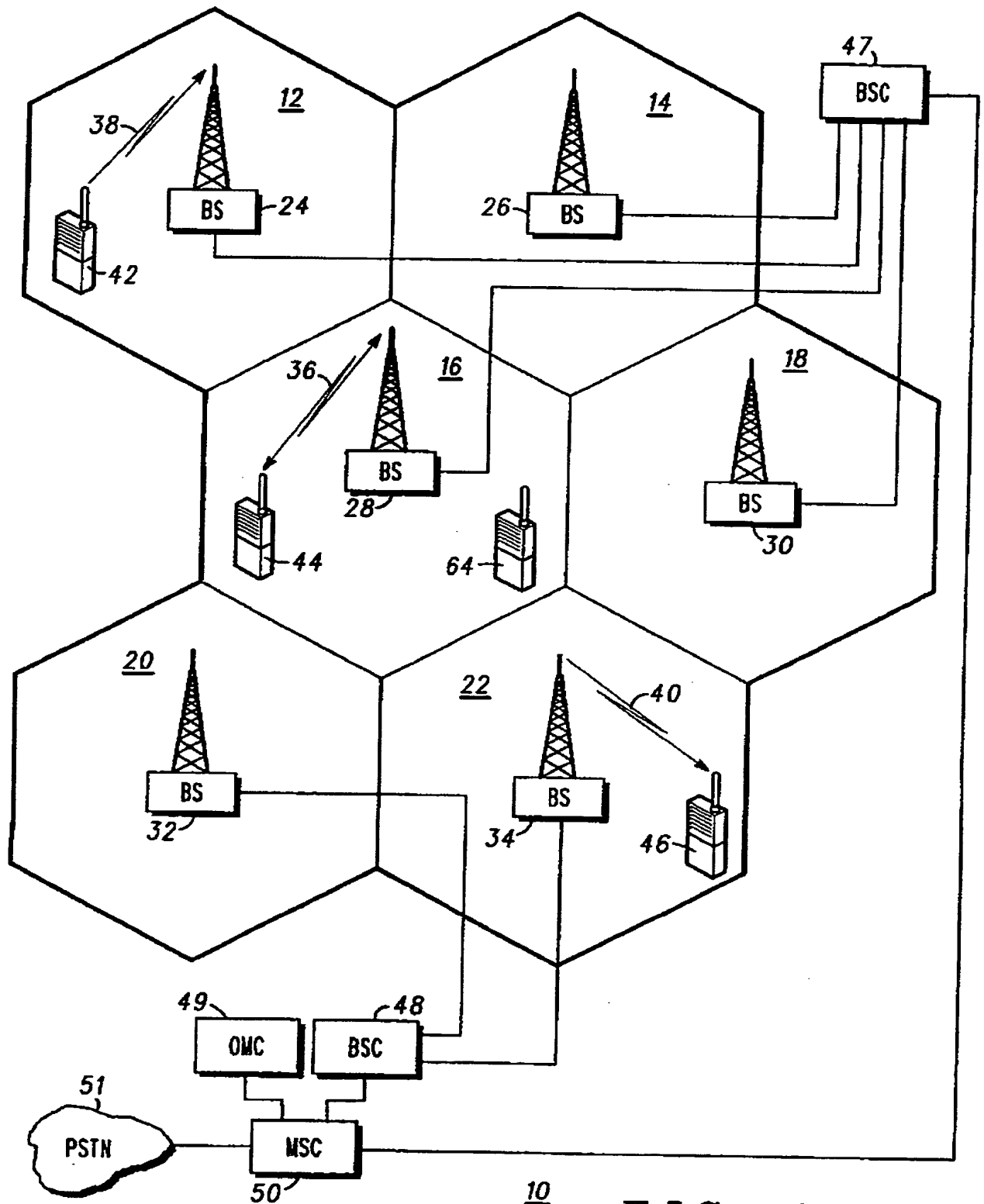


FIG. 1

LIST No.	BCCH- ARFCN	BSIC
1	10	6
2	14	3
3	12	5
⋮	⋮	⋮
32	20	16

FIG. 2

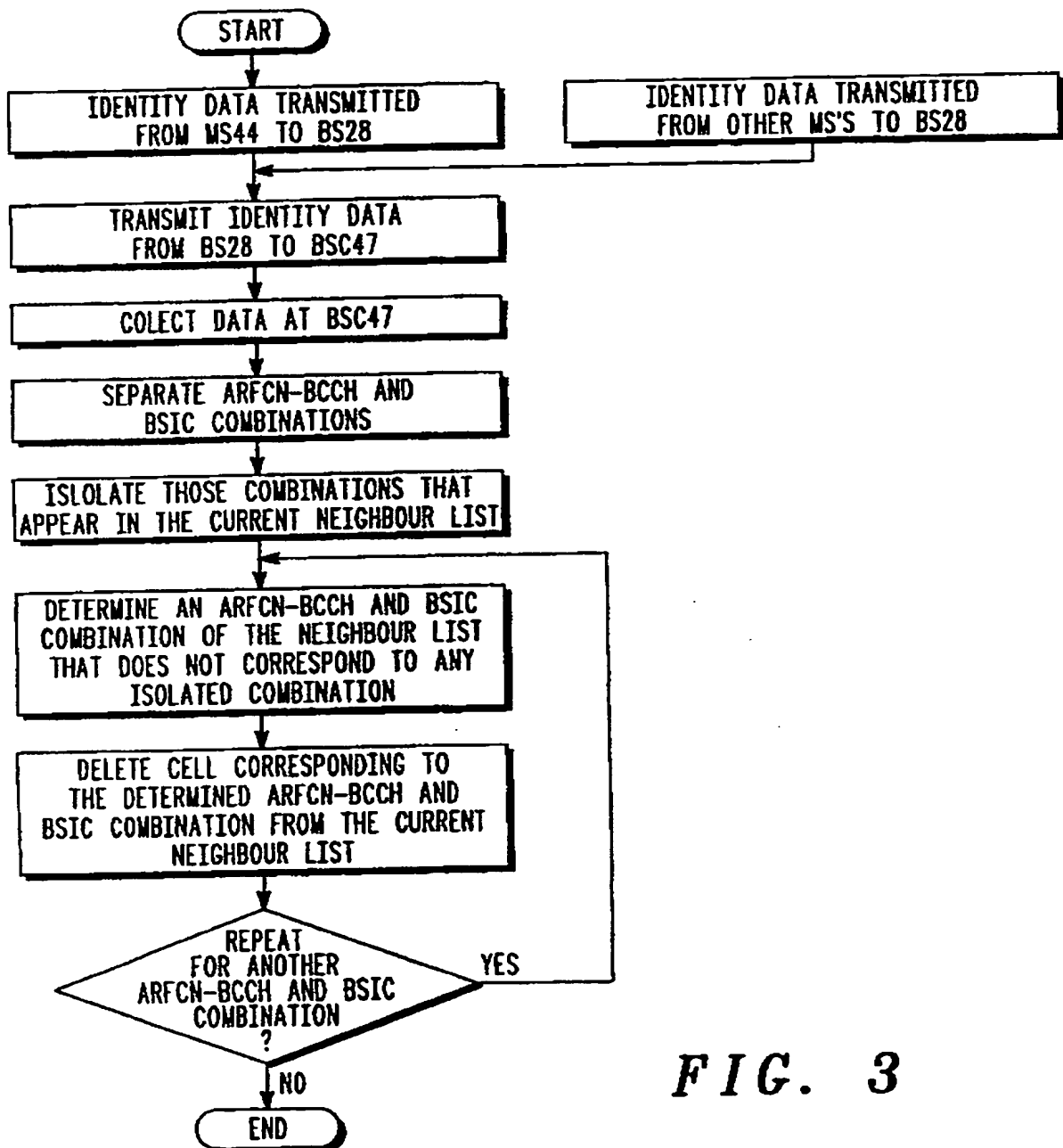


FIG. 3

METHOD OF INVESTIGATING AND METHOD OF ALTERING A  
TOPOLOGY OF A CELLULAR COMMUNICATION SYSTEM.

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Field of the Invention

The present invention relates to a method of investigating  
a topology of a cellular communication system. The  
present invention also relates to a method of altering a  
10 topology of a cellular communication system.

Background of the Invention

In a cellular communication system the area over which  
15 service is provided is divided into a number of smaller  
areas called cells. Each cell is served from a base station,  
which has a corresponding antenna or antennas for  
transmission to and reception from a user station, normally  
a mobile station. Within the system, a user station is at  
20 any one time assigned to a given cell, known as the serving  
cell. In such a system a user station can be handed over to  
another cell. Handover can be initiated for various  
different reasons. One typical reason is that the subscriber  
has moved or is moving to a location where it would be  
25 more suitably assigned to an alternative cell. Procedures  
and criteria for handover are designated in the system, and  
such features are well known in the art.

In such a cellular communication system an allocation is  
30 made, for each cell, of those specific other cells that will

serve as candidate handover cells. The list of allocated cells for a given cell is typically called a current neighbour list. For a given cell the candidate handover cells are in general chosen from those located in close geographical proximity to the given cell, and in the absence of any other factors could in theory be allocated on a simple basis such as all those cells geographically surrounding the given cell. However, due to factors such as geographical and construction features, e.g. obstructions, subscriber densities, subscriber movement patterns, and uneven sized or shaped cells, in practice it is necessary to allocate cells on a less systematic basis. The above described allocation arrangement of candidate handover relationships between the cells of a cellular communications system is termed the topology of the system.

In a given cellular communication system there will typically be a maximum number of cells that can be contained on the current neighbour list of a cell. In a Global System for Mobile communications (GSM) system, for example, this maximum number is 32.

A feature of the topology of a cellular communication system is that it requires repeated investigation and alteration. Alteration typically means either the addition of a cell to the neighbour list or the deletion of a cell from the neighbour list. Addition of a cell to the current neighbour list is desirable when a cell that would usefully carry out a significant number of handovers were it on the neighbour list is not currently on the neighbour list for some reason or

- other. The reason might be the existing topology was imperfectly planned, or it might be that circumstances have changed since the topology was last determined. Many factors that influence the suitability of the current topology can change, e.g. new buildings are built, new cells are added in the vicinity, subscriber usage levels and movement patterns change, and so on. Deletion of a cell from the current neighbour list is desirable when a cell is included in the current neighbour list of a given cell but in practice is seldomly or never actually handed over to that given cell. Deletion of a cell is also desirable when handover to that cell degrades the overall system performance.
- 15 The prior art method of investigating and altering the topology is based on drive testing, which involves an operator literally driving around the coverage area of a cell in a vehicle. Drive routes, that is routes that are intended to be representative of the communications traffic contained in the cell under investigation, are chosen. The drive-testing method involves driving the chosen routes making multiple telephone calls in both the mobile-to-land and the land-to-mobile directions. The duration of the calls should reflect the typical holding time of standard subscriber calls for the particular drive route. The information from each call is recorded and post-processed. The drive test equipment is used to provide a breakdown of call successes and failures. It can also be used to highlight call quality. The recorded information is also processed to target poor call success rates and poor call quality. In practice a team of

testers is required to carry out investigation of the topology of given cells for a particular region of a system.

- Drive-testing entails a number of significant disadvantages.
- 5    Complicated equipment is required by each team of drive-testers. In addition GPS position locating equipment is required for any subsequent analysis of the data since this fundamentally requires position information. Moreover the whole procedure is labour intensive and time-consuming.
  - 10   Being time-consuming not only involves direct cost implications but also has the disadvantage that the accuracy of the results achieved can be affected by changes during the time required for the testing and also it places restrictions on the network operator who cannot make
  - 15   changes to the system topology or other parameters during the period of drive-testing.
  - 20   Another disadvantage is that detailed local knowledge is required to choose realistic drive routes. Moreover, how ever well chosen, such routes are merely representative of real usage in the cell, and no correlation is made between the chosen drive-test routes and real subscriber usage
  - 25   patterns.
  - 30   Yet another disadvantage is that drive-testing ,as conventionally carried out in a vehicle, does not provide adequate correlation with respect to subscriber usage in which the subscribers move on foot, which usage is

increasing with the use of hand-portable mobiles, in particularly within the office environment.

Thus it would be advantageous to overcome the above  
5 disadvantages of drive-testing and provide an improved method of investigating and altering a topology of a cellular communication system.

### Summary of the Invention

10

The present invention provides a method of investigating a topology of a cellular communication system in which system one or more mobile stations assigned to a serving cell acquires identity data related to identities of a  
15 plurality of cells other than said serving cell, said system comprising a current neighbour list comprising an identity of one or more cells which are allocated as candidate handover cells in a current topology of the system; the method comprising the steps of:  
20 a) collecting at least some of said identity data to provide collected data;  
b) determining, at least in part from said collected data, the identity of a first said other cell; and  
c) comparing the identity of said first said other cell with  
25 the cell identities of the current neighbour list.

The present invention also provides a method of altering a topology of a cellular communication system in which  
30 cell acquires identity data related to identities of a plurality



- of cells other than said serving cell, said system comprising a current neighbour list comprising an identity of one or more cells which are allocated as candidate handover cells in a current topology of the system;
- 5 the method comprising the steps of:
- a) collecting at least some of said identity data to provide collected data;
  - b) determining, at least in part from said collected data, the identity of a first said other cell;
  - 10 c) comparing the identity of said first said other cell with the cell identities of the current neighbour list; and
  - d) altering the current neighbour list responsive to said comparison step c).
- 15 Advantageous embodiments of the invention are as detailed in the dependent claims.

The methods according to the present invention achieve the advantage that investigation and alteration of the topology

20 is carried out without the need for drive-testing, thus overcoming the labour intensive and time-consuming disadvantages of drive-testing. The present invention achieves assessment of position dependent and moving factors without requiring to actually be on the move and

25 locate positions, as is the case with drive-testing. Thus position location equipment is not required. Yet another advantage is that the results achieved are more fully representative of the actual subscriber usage in a cell, thus overcoming the disadvantage of drive-testing that the

30 drive-test routes are only partially representative of real

usage and are also dependent on local knowledge for their planning. In this respect the present invention also has the advantage that the results achieved take full account of the usage of subscribers moving on foot.

5

### Brief Description of the Drawings

FIG. 1 is an illustration of a typical cellular communication system that may be used with the present invention.

10 FIG. 2 shows a representation of a neighbour list.

FIG. 3 is a flow diagram outlining the method of a preferred embodiment of the present invention.

### Description of Preferred Embodiments of the Invention

15

A first preferred embodiment relates to a cellular communication system which is GSM system, although it will be appreciated that the invention is not limited to such a system and could equally be used in other time division multiple access (TDMA) systems, in code division multiple access (CDMA) systems, or other cellular communication systems including combined TDMA/CDMA systems.

20

FIG. 1 illustrates a typical cellular communication system 25 10 having a coverage area formed by a number of cells 12-22. A conventional schematic representation showing a hexagonal cell pattern has been used to depict the cell areas, but in practice the shape and size of each cell will be different. In each cell, often at the centre, there is located 30 a base station (BS) 24-34 which controls communications

traffic 36, 38, 40 in its cell in accordance with procedures known to one skilled in the art. Each base station 24 - 34 may receive 38 and transmit 40 signals from/to mobile stations (MS) 42 - 46 that move throughout the  
5 communication system 10. In the preferred embodiment each of base stations 24, 26, 28 and 30 is coupled to mobile services switching centre (MSC) 50 through one base station controller (BSC) 47 and each of base stations 32 and 34 is coupled to MSC 50 through another BSC 48. An  
10 operations and maintenance centre (OMC) 49 is also coupled to MSC 50. Subject to the size of the communications system, OMC 49 may be responsible for the whole system or alternatively there may be a number of OMCs provided on a regional basis. MSC 50 is coupled to a public switched  
15 telephone network (PSTN) 51.

MS44 is assigned to BS28 as its serving cell by means of the following procedure. When MS 44 is switched on, it scans, by processes well known in the art, in an attempt to receive  
20 signals from base stations. In this scanning stage the MS scans using all the frequencies of the system. MS 44 receives signals from BS 28 and, in this example BSs 24, 26, 30 32 and 34. The MS determines which received signal is of the greatest strength, and then communicates to the  
25 corresponding BS, in the present case BS28, that it wishes to be connected to the system. BS28 undertakes a dialogue with MS44 to establish a communication path, and also at this stage interrogates the MS 44 to ascertain details from it including its identity. The identity of MS 44 and other  
30 details, such as cryptographic information, are transmitted

by the BS to the BSC 47, and on to the MSC 50. The MSC 50 stores these details so that when the mobile station is paged it can route the call from the PSTN 51 via the MSC 50 to BSC 47, and on to BS28, where communication between  
5 MS 44 and the system occurs. At this stage of the assignment procedure MS 44 becomes under the control of BS28. Control information is transmitted from BS28 to MS44. This control information includes inter-alia a control message indicating which sub-set of frequencies should be  
10 scanned from now on. The frequencies of the sub-set correspond to the frequencies employed by the BSs on the current neighbour list of BS28. The current neighbour list is explained more fully below. In addition, in the present embodiment, the control information includes an  
15 instruction that MS 44 should also scan some of the other frequencies used in the system. In the communication system, certain frequencies, i.e. frequency channels, may be dedicated to carrying control messages and certain other frequencies, i.e. frequency channels, may be dedicated to  
20 carrying communication traffic. One choice of which other frequencies are to be scanned is that of choosing to instruct the mobile station to scan all the frequencies that are used for control messages in the system, as opposed to the frequencies that are used for communication traffic. The  
25 outcome of the assignment procedure is that MS44 is assigned to BS28 which is therefore termed its serving cell. Thereafter MS44 will communicate with BS28 in response to a page or on a periodic basis to confirm to BS28 that it is still operating normally.

30

MS 44 will remain assigned to BS28 as its serving cell until it is either turned off, or handed over to another cell in the vicinity. Handover to another cell involves the current neighbour list, which is now explained in detail.

5

In the system of the present embodiment it is necessary to allocate, for each BS, those specific other BSs that will serve as candidate handover BSs. The list of identities of allocated handover BSs, and hence allocated handover cells, is called the neighbour list. In the system according to the present embodiment the neighbour list is stored at the base station. However, in other systems it could alternatively be stored at the BSC, the OMC, or indeed even remotely. The candidate handover BSs in the present example of BS 28 are chosen from those located in close geographical proximity to the cell area of BS28, and in the absence of any other factors will be allocated on a simple basis of all those cells geographically surrounding it. It is noted however, that were other factors influential, such as geographical and construction features, e.g. obstructions, subscriber densities, subscriber movement patterns, and uneven sized or shaped cells, then it would be preferable to allocate cells on a less systematic basis. The resulting allocation arrangement of candidate handover relationships between the BSs (and hence cells) of the cellular communications system is termed the topology of the system. In the present embodiment each of the five cells shown schematically around cell 16 in FIG. 1, that is cells 12, 14, 18, 20 and 22 are present on the current neighbour list of BS 28. Moreover, in the present

30

embodiment, no further cells are in the current neighbour list. It is pointed out however that in general, in a given cellular communication system there will typically be a maximum number of cells that can be contained on the  
5 current neighbour list of a cell.

In the GSM system of the present embodiment each BS broadcasts on its control frequency continuously in the  
10 form of a broadcast control channel (BCCH). In the present GSM case the control channel frequency is in the form of the absolute radio frequency channel number (ARFCN). Encoded in the BCCH is a further BS identifier termed the BS identifier code (BSIC). The overall BCCH-ARFCN and BSIC  
15 combination thus forms identity data relating to the identity of the base station, i.e. identity data relating to the identity of the cell.

As previously mentioned, MS44 scans the frequencies  
20 determined by the control message from BS 28, i.e. the frequencies contained in the so-called scan list of BS28. By virtue of receiving the control frequency signals, MS44 determines a signal strength metric, that is a measure of the strength of the signal in the case of each received BCCH.  
25 It also decodes the BSIC. Thus MS44 which is assigned to BS28 as its serving cell acquires identity data and signal metric data in the form of three pieces of information from each BS, i.e. other cell, it has successfully scanned, namely the BSIC, the signal strength metric, and the respective  
30 control channel frequency. In the present GSM case the

control channel frequency is in the form of an ARFCN index. These three pieces of information are attached together in the form of a module of data. Respective modules of data determined from a plurality of different BSs, i.e. a plurality of cells other than the serving cell, are passed back to BS28. In the present GSM embodiment, MS44 ranks the modules of data on the basis of the signal strength metric, and transmits only the six highest ranked modules of data to BS28. These are transmitted to BS28 in the form of a measurement report. Such a measurement report is fully defined in ETSI GSM Specifications 4.08.

The case of handover due to signal strength considerations will now be considered. However, it will be appreciated that this represents just one of a number of possible reasons for handover which are well known in the art.

As MS44, which is assigned to and in communication with BS28, moves towards BS32, the relative level of the signal strength metric from adjoining BS32 will increase, whilst conversely the serving cell signal strength will decrease. This will be reflected in the appropriate parts of the measurement reports. Within BS28 the BCCH-ARFCN and BSIC combination is converted to a BS identity, in this case BS32. Such a conversion can only occur if the BCCH-ARFCN and BSIC combination and BS identity are contained in the neighbour list. FIG. 2 schematically shows a representation of a neighbour list, from which it can be seen how a BCCH-ARFCN and BSIC combination corresponds to a specific BS identity. The inclusion of BS 32 in the

current neighbour list of BS28 plays a role in the remainder of the handover process from BS28 to BS32 which is now described.

- 5 When the signal strength metric from BS32 exceeds that of BS28 (the serving cell) by more than the handover margin, which in this case is 6dB, then MS44 is instructed by BS28 or some other system element to become assigned to BS32 as its serving cell instead of BS28. This re-assignment
- 10 procedure involves changing frequency of transmission so that MS44 is on a frequency utilised by BS32. Also, in the present GSM embodiment the timeslot (TDMA frame position) is additionally specified. As in the original assignment procedure, during handover a scan list of
- 15 frequencies pertinent to BS32 is received by MS44. The measurement reports between MS44 and BS32 differ over those earlier ones between MS44 and BS28 in that the serving information now relates to BS32, whilst the other modules of information will not relate to all the same ones
- 20 that were present in the case of BS28. In the process of handing over, information is transmitted between BS28 and BS32 so that the receiving cell (BS32) knows that MS44 will now become under its control. Signalling information flows between BSCs 47 and 48 and then BS 28 and 32 via the
- 25 MSC, whilst any connection to the PSTN is transparent. The BS and BSC elements will update counter records to reflect that handover has occurred, and the records will subsequently be transmitted to OMC 49 for storage.



The method of this preferred embodiment is outlined in flow diagram form in FIG. 3. The data constituting the measurement reports transmitted from MS44 to BS28, which thus includes the identity data, is further  
5 transmitted from BS 28 to BSC 47, where it is collected to provide collected data. In the present embodiment the corresponding data from a plurality of other mobile stations assigned to BS28 is also transmitted to BS28 and further transmitted from BS 28 to BSC 47, but it is pointed out that  
10 the invention may nevertheless be usefully employed using the data from just one mobile station. It is noted that the data could according to other embodiments of this invention be collected at BS 28 itself, or alternatively at other network nodes. In the present embodiment the way  
15 in which the step of determining, at least in part from the collected data, the identity of the one or more of the cells other than the serving cell, and also the step of comparing the identity of the one or more of the cells other than the serving cell with the cell identities of the current neighbour  
20 list is carried out, is as follows. From the collected data the respective ARFCN-BCCH and BSIC combinations from the modules of information within each measurement report are separated and then compared against the list of such combinations held on the current neighbour list. This  
25 procedure is implemented by connecting a computer to the BSC and using routine computer methods well known in the art. An alternative means on implementing these procedures would be to use a computer or part of a computer integrated in the BSC or BS itself. Those identities  
30 and corresponding ARFCN-BCCH and BSIC combinations that

appear in the current neighbour list are isolated. This is also carried out by routine computer methods. Any cell identities and corresponding ARFCN-BCCH and BSIC combinations on the current neighbour list that are not in the list of isolated ARFCN-BCCH and BSIC combinations have thus not made any contribution to the assessment process for handover represented by the collected data. Such a cell can be considered to be inappropriately contained in the current neighbour list. Consequently as a means of improving the topology of the system, the topology of the system is altered by altering the current neighbour list by deleting this cell from the current neighbour list.

The above deletion procedure may then be repeated for another ARFCN-BCCH and BSIC combination, i.e. cell identity, on the current neighbour list that is not in the list of isolated ARFCN-BCCH and BSIC combinations, and so on.

In carrying out the present embodiment a statistical sampling procedure is employed. The identity data is in the form of modules of data and the statistical sampling procedure comprises sampling a selection of the modules of data. More particularly the modules of data are constituted by the GSM measurement reports which are subjected to a statistical sampling procedure. In other words not every measurement report need be fully processed. In the present embodiment many tens of thousand of measurement reports, are processed so that the topology calculations are carried out with a high degree of accuracy. This provides the advantage that the results are not biased

for example by a single long communication between MS44 and BS28, since instead results from a plurality of communications between MS44 and BS28 are used. Thus information across the whole of the coverage area of BS28, i.e. over the whole cell, can be provided. Also in the present embodiment, data from one or more other mobile stations 64 within the cell may also be collected, sampled and used in the calculations. By using data from a plurality of communications, the measurement report data can originate from users moving over the whole cell, due to the mobility of the mobile stations within the GSM system of the present embodiment. The same advantages can also be achieved in the case of any other mobile communication system. Sampling the measurement reports is implemented such that from the series of measurement reports being collected, one report is analysed, then a number are skipped, i.e. ignored, then the next measurement report is analysed, then a number are skipped, and so on. One advantageous way of implementing this is to select every  $n$ th measurement report where  $n$  is an integer. The sampling procedure creates a sub-set of the whole data set of statistics. This process allows more information to be processed for a given size of computer memory and processing capability. Furthermore, many measurement reports are similar, so by adopting a sampling procedure more variants of information modules within the measurement report can be listed with the given computer. Alternative statistical sampling approaches can be used in the present embodiment, and is chosen by the skilled person according to the prevalent patterns of data

and desired or available amount of processing capacity. For example, the data can be collected on a sampling basis and then all the collected data further processed, and this may include collecting from only some of the mobile stations in a  
5 cell.

The above preferred embodiment is hereinafter termed the first deletion embodiment. A second deletion embodiment is implemented in the same fashion as the first deletion  
10 embodiment, except as follows. An amount or rate of occurrences at which respective ARFCN-BCCH and BSIC combinations are present in the collected data is determined using routine computer methods well known in the art. Deletion from the neighbour list is performed for a  
15 cell identity corresponding to an ARFCN-BCCH and BSIC combination for which the amount or rate of occurrences fulfils a predetermined criteria. In the present embodiment a cell identity is deleted from the current neighbour list if its ARFCN-BCCH and BSIC combination fails to constitute at  
20 least 1% of the total ARFCN-BCCH and BSIC combinations forming the collected data.

In the above deletion embodiments, alteration of the topology includes the step of deleting a cell identity from  
25 the current neighbour list. In another preferred embodiment, hereinafter termed the first addition embodiment, alteration includes the step of adding a cell identity to the current neighbour list, rather than deletion. The first addition embodiment is now described, and where  
30 applicable, items and procedures mentioned relate directly

to those already mentioned in the above description of the deletion embodiments.

As already described above, during the assignment  
5 procedure MS 44 becomes under the control of BS28.  
Control information is transmitted from BS28 to MS44. This  
control information includes inter-alia a control message  
indicating which sub-set of frequencies should be scanned  
10 from now on. The frequencies of the sub-set correspond to  
the frequencies employed by the BSs on the current  
neighbour list of BS28. In addition, in the present  
embodiment, the control information includes an  
instruction that MS 44 should also scan some of the other  
15 frequencies used in the system. In the communication  
system certain frequencies, i.e. frequency channels, may be  
dedicated to carrying control messages and certain other  
frequencies, i.e. frequency channels, may be dedicated to  
carrying communication traffic. One choice of which other  
20 frequencies are to be scanned is that of choosing to instruct  
the mobile station to scan all the frequencies that are used  
for control messages in the system, as opposed to the  
frequencies that are used for communication traffic.

The first addition embodiment is employed when, on  
25 comparing the identity data related to the identities of a  
plurality of cells other than the serving cell, which in the  
present case consists of ARFCN-BCCH and BSIC  
combinations, to the neighbour list in BS28, a combination  
is found that has no cross reference to a BS identity, i.e. the  
30 ARFCN-BCCH and BSIC combination is not on the neighbour

list. That is, the identity data has come from one of the other frequencies selected to be scanned, as explained in the previous paragraph.

- 5 In the present addition embodiment, since the ARFCN-BCCH and BSIC combination was not on the neighbour list, the identity of the base station, i.e. cell, has not yet been determined. Thus in the present embodiment, the comparison step referred to as c) in the appended claims is  
10 carried out before the determination step referred to as b). It is thus emphasised that the various steps can be carried out in different order according to the present invention, depending merely on when it is most convenient or economical to implement each step. In the present case, it is  
15 directly evident to the skilled person that it is not necessary to identify the cell under investigation until it has been decided whether to add it to the neighbour list. However, in other circumstances the skilled person may, for evident reasons, choose to identify the cell first. Similarly,  
20 depending on the details of any particular system to which the present invention is applied, the skilled person may under the present invention elect to carry out two or more of the steps on an iterative basis, for example depending on the system it may be necessary or desirable to use an  
25 iterative process involving the determining step b) and the comparison step c).

Since the ARFCN-BCCH and BSIC combination corresponds to the identity of a cell identity that is not on the current  
30 neighbour list but is successfully received by the scanning

process, it represents a cell identity that could possibly have made a contribution to the assessment process for handover represented by the collected data had it in fact been on the neighbour list. Likewise it would be  
5 advantageous should that cell identity be included in the neighbour list in future. Consequently as a means of improving the topology of the system, the topology of the system is altered by altering the current neighbour list by adding this cell to the current neighbour list.

10

In the present first addition embodiment the identity of the cell corresponding to the ARFCN-BCCH and BSIC combination that it has been decided should be added to the current neighbour list is then determined, at least in  
15 part from the collected data. Thus, in this embodiment, determining step b) of the claims is carried out after comparing step c), the order of the steps in general being chosen by the skilled person as mentioned already above in the description of the present first addition embodiment.

20

In the present first addition embodiment, which relates to a GSM system, the determination of the identity of the cell is achieved by applying the assumption that the ARFCN-BCCH and BSIC combination is unique to a particular BS. If  
25 in certain circumstances this assumption proves to be imperfect, then supplementary information, for example the X and Y co-ordinates of each BS in the system, can be used. The distance between the serving BS and all other BSs is calculated, using trigonometric calculations well known to  
30 those in the art to provide a database having the ARFCN-

BCCH and BSIC combinations of different BSs in  
correspondence with their respective distances from the  
serving BS. This database is sorted according to ARFCN-  
BCCH and BSIC combination and in ascending distance from  
5 the serving BS. The database is searched to find those cells  
that have the candidate ARFCN-BCCH and BSIC combination  
and have an appropriate distance from the serving BS. The  
distance is appropriate to range and coverage of the serving  
cell and its surrounding neighbours. For example in a city  
10 cells a few kilometres away would be considered, whereas  
in country areas the neighbours may be at a greater  
distance. Further information in terms of the antenna  
orientation and the predicted signal strength in the serving  
cell's coverage area can be used to distinguish when two  
15 neighbouring cells have similar distances from the serving  
cell and the same ARFCN-BCCH and BSIC combination in a  
system.

In the addition embodiment mentioned above, after  
20 adding, or determining to add, a particular ARFCN-BCCH  
and BSIC combination to the current neighbour list, another  
ARFCN-BCCH and BSIC combination can then be processed.

As mentioned above the module of data acquired by MS44  
25 includes a signal strength metric in addition to the BSIC and  
the respective control channel frequency. In a further  
embodiment, hereinafter termed the third deletion  
embodiment, this signal strength metric is additionally  
employed.

30



The identities of the cells other than the serving cell are repeatedly ranked in ranking positions in a ranking order according to the respective signal strength metrics. That is, each module of information is ranked according to the signal strength metric, where each module of information comprises an ARFCN-BCCH and BSIC combination and an attached signal strength metric value. In a GSM system the six cell identities with the highest ranked signal strength metrics are reported in the measurement report, the six ranking positions being termed neighbour positions, in which neighbour position 1 represents the highest signal strength. For a particular cell identity, which in this embodiment is in the form of a particular ARFCN-BCCH and BSIC combination, the extent that this respective other cell identity appears in the six respective ranking positions in the sampled data is then determined. This can be performed using an automated procedure using known computer methods.

In the present embodiment deletion is carried out for a particular ARFCN-BCCH and BSIC combination if it fulfils a predetermined criteria consisting of whether it appears only in a predetermined position or range of positions of the six ranking positions. In the present embodiment deletion is carried out if the ARFCN-BCCH and BSIC combination has only appeared in positions 3 to 6. An alternative possibility is to carry out deletion if the ARFCN-BCCH and BSIC combination has only appeared in positions 4 to 6.

30

In the above described third deletion embodiment it is also possible to include in the predetermined criteria the earlier described function related to an amount or rate of occurrences at which respective identities of the other

5 ARFCN-BCCH and BSIC combinations, i.e. cells, are indicated in the collected identity data. For example the criteria can be that a particular ARFCN-BCCH and BSIC combination, i.e. cell identity, is deleted from the current neighbour list if it only appears in positions 4 to 6 and if the combination fails

10 to constitute at least 0.5% of the total ARFCN-BCCH and BSIC combinations forming the collected data.

In a further embodiment, hereinafter termed the second addition embodiment, the ranking positions described

15 above are employed. In this embodiment the six neighbour positions of the measurement report are allocated into three ranges consisting of neighbour position 1, neighbour positions 2 to 3, and neighbour positions 4 to 6. The predetermined criteria employed for addition of a cell

20 identity to the current neighbour list is a function of these three ranges. It will be appreciated that numerous possible functions of these ranges can be employed to advantageous effect, and that the exact choice will be made by the skilled person depending on the particular system requirements.

25 One example for the predetermined criteria can be that the particular ARFCN-BCCH and BSIC combination has been reported in neighbour position 1 in more than 10% of the measurement reports sampled or that the particular ARFCN-BCCH and BSIC combination has been reported in

the range consisting of neighbour positions 2 to 3 in more than 30% of the measurement reports sampled.

- 5 In all the embodiments described above, after deleting or adding, or determining to delete or add, a particular ARFCN-BCCH and BSIC combination from or to the current neighbour list, another ARFCN-BCCH and BSIC combination can then be processed.

**CLAIMS**

1. A method of investigating a topology of a cellular  
5 communication system in which system one or more  
mobile stations assigned to a serving cell  
acquires identity data related to identities of a plurality of  
cells other than said serving cell,  
said system comprising a current neighbour list comprising  
10 an identity of one or more cells which are allocated as  
candidate handover cells in a current topology of the  
system;  
the method comprising the steps of:  
a) collecting at least some of said identity data to provide  
15 collected data;  
b) determining, at least in part from said collected data, the  
identity of a first said other cell; and  
c) comparing the identity of said first said other cell with  
the cell identities of the current neighbour list.  
20
2. A method according to claim 1 wherein said steps a) -  
c) are performed for a plurality of said other cells.
3. A method according to claim 1 wherein said steps a) -  
25 c) are performed for a plurality of mobile stations  
assigned to said serving cell.
4. A method according to claim 1 wherein one or more  
of steps a), b) and c) is performed according to a statistical  
30 sampling procedure.

5. A method according to claim 4 wherein said identity data is in the form of modules of data and said statistical sampling procedure comprises sampling a selection of said modules of data.

6. A method according to claim 5 wherein said system is a GSM system, said modules of data are measurement reports, and said selection comprises selecting every  $n$ th measurement report where  $n$  is an integer.

7. A method according to claim 1 wherein said identity data is acquired by said one or more mobile stations by scanning said other cells and/or said serving cell.

8. A method of altering a topology of a cellular communication system in which system one or more mobile stations assigned to a serving cell acquires identity data related to identities of a plurality of cells other than said serving cell, said system comprising a current neighbour list comprising an identity of one or more cells which are allocated as candidate handover cells in a current topology of the system; the method comprising the steps of:

- a) collecting at least some of said identity data to provide collected data;
- b) determining, at least in part from said collected data, the identity of a first said other cell;
- c) comparing the identity of said first said other cell with the cell identities of the current neighbour list; and

d) altering the current neighbour list responsive to said step c).

5 9. A method according to claim 8 wherein said steps a) - c) are performed for a plurality of said other cells.

10 10. A method according to claim 8 wherein said steps a) - c) are performed for a plurality of mobile stations assigned to said serving cell.

11. A method according to claim 8 wherein one or more of steps a), b) and c) is performed according to a statistical sampling procedure.

15 12. A method according to claim 11 wherein said identity data is in the form of modules of data and said statistical sampling procedure comprises sampling a selection of said modules of data.

20 13. A method according to claim 12 wherein said system is a GSM system, said modules of data are measurement reports, and said selection comprises selecting every nth measurement report where n is an integer.

25 14. A method according to claim 8 wherein said identity data is acquired by said one or more mobile stations by scanning said other cells and/or said serving cell.

15. A method according to claim 8 or 9 wherein said step d) comprises deleting from the current neighbour list the identity of a said other cell which is in the current neighbour list and which is not included in those identity or  
5 identities determined by said step b).

16. A method according to claim 9 further comprising determining an amount or rate of occurrences at which respective identities of said other cells are indicated in said  
10 collected data; and wherein said step d) comprises deleting from the current neighbour list the identity of a said other cell for which said amount or rate of occurrences fulfils a predetermined criteria.

15 17. A method according to claim 9 wherein identities of said other cells are repeatedly ranked in ranking positions in a ranking order according to a signal metric, thus providing ranking data, and said step d) is performed responsive to a predetermined criteria which includes a  
20 function relating to what extent a respective other cell identity appears in a predetermined position or range of positions within said ranking order.

18. A method according to claim 17 wherein said  
25 predetermined criteria is that a said other cell appears only in a predetermined position or range of positions within said ranking order and said step d) comprises deleting from the current neighbour list a said other cell identity.  
30

19. A method according to claim 18 wherein said ranking positions are six neighbour positions in a measurement report of a GSM system and said predetermined range of positions is either positions 3 to 6 or positions 4 to 6.
- 5
20. A method according to claim 17 wherein said predetermined criteria also includes a function related to an amount or rate of occurrences at which respective identities of said other cells are indicated in said collected data.
- 10
21. A method according to claim 8 or 9 wherein said step d) comprises adding to the current neighbour list the identity of a said other cell which is not in the current neighbour list and which is included in those identity or identities determined by said step b).
- 15
22. A method according to claim 17 wherein said ranking positions are six neighbour positions in a measurement report of a GSM system; said function of said predetermined criteria includes allocation of said six neighbour positions into three ranges consisting of neighbour position 1, neighbour positions 2 to 3, and neighbour positions 4 to 6 respectively; and said step d) comprises adding to the current neighbour list the identity of a said other cell which is not in the current neighbour list.
- 20
- 25
23. A method of investigating a topology of a cellular communication system substantially as hereinbefore
- 30



described and with reference to the accompanying drawings.

- 5 24. A method of altering a topology of a cellular communication system substantially as hereinbefore described and with reference to the accompanying drawings.



# The Patent Office

31

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Claims searched: All

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## Patents Act 1977 Search Report under Section 17

### Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): H4L (LDSHE, LDSHS, LDSHX)

Int Cl (Ed.6):

Other: Online Database: WPI

### Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	WO97/32445 A1 (ERICSSON) p.15 line 26 - p.29 line 1	1 & 8 at least
X	WO9706648 A1 (ERICSSON) p.14 line 18 - p.27 line 26	1 & 8 at least

X Document indicating lack of novelty or inventive step  
Y Document indicating lack of inventive step if combined with one or more other documents of same category.  
& Member of the same patent family

A Document indicating technological background and/or state of the art.  
P Document published on or after the declared priority date but before the filing date of this invention.  
E Patent document published on or after, but with priority date earlier than, the filing date of this application.

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(54) Abstract Title  
**Method of altering a neighbour cell list in a cellular communication system**

(57) Each cell of a cellular communication system has a neighbour list containing the identities of neighbouring cells suitable for handover. Mobile stations in a serving cell scan to detect the identities and signal strengths of other cells and report the results to the serving cell base station. Other cells which are detected but are not on the neighbour list are added to the list while any cells which are on the list but not detected are deleted from the list. Statistical sampling of a large number of reports is used to accurately determine a neighbour list. Cells may be added or deleted from the list depending on the rate or number of times they are detected. The signal strength of the detected cells can be used to rank the cells so that addition or deletion from the neighbour list only occurs if the detected cell is ranked in a predetermined position or range of positions. A combination of detection rate and signal strength ranking can be used as criteria for adding or deleting from the list.

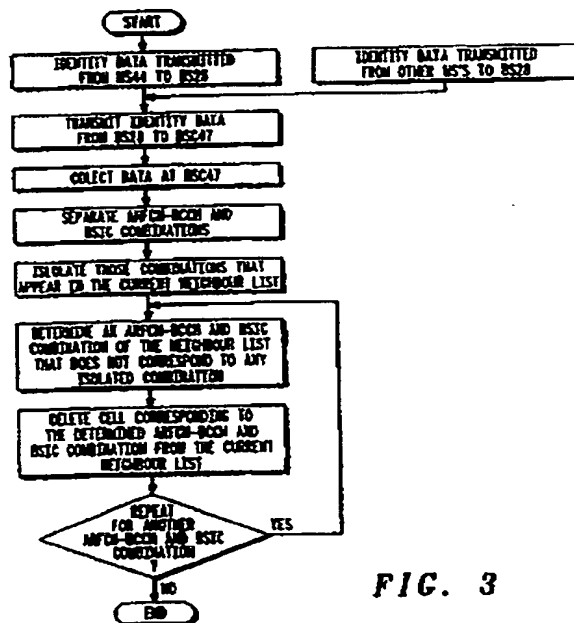


FIG. 3

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

METHOD OF INVESTIGATING AND METHOD OF ALTERING A  
TOPOLOGY OF A CELLULAR COMMUNICATION SYSTEM.

5

Field of the Invention

The present invention relates to a method of investigating  
a topology of a cellular communication system. The  
present invention also relates to a method of altering a  
10 topology of a cellular communication system.

Background of the Invention

In a cellular communication system the area over which  
15 service is provided is divided into a number of smaller  
areas called cells. Each cell is served from a base station,  
which has a corresponding antenna or antennas for  
transmission to and reception from a user station, normally  
a mobile station. Within the system, a user station is at  
20 any one time assigned to a given cell, known as the serving  
cell. In such a system a user station can be handed over to  
another cell. Handover can be initiated for various  
different reasons. One typical reason is that the subscriber  
has moved or is moving to a location where it would be  
25 more suitably assigned to an alternative cell. Procedures  
and criteria for handover are designated in the system, and  
such features are well known in the art.

In such a cellular communication system an allocation is  
30 made, for each cell, of those specific other cells that will

serve as candidate handover cells. The list of allocated cells for a given cell is typically called a current neighbour list. For a given cell the candidate handover cells are in general chosen from those located in close geographical proximity to the given cell, and in the absence of any other factors could in theory be allocated on a simple basis such as all those cells geographically surrounding the given cell. However, due to factors such as geographical and construction features, e.g. obstructions, subscriber densities, subscriber movement patterns, and uneven sized or shaped cells, in practice it is necessary to allocate cells on a less systematic basis. The above described allocation arrangement of candidate handover relationships between the cells of a cellular communications system is termed the topology of the system.

In a given cellular communication system there will typically be a maximum number of cells that can be contained on the current neighbour list of a cell. In a Global System for Mobile communications (GSM) system, for example, this maximum number is 32.

A feature of the topology of a cellular communication system is that it requires repeated investigation and alteration. Alteration typically means either the addition of a cell to the neighbour list or the deletion of a cell from the neighbour list. Addition of a cell to the current neighbour list is desirable when a cell that would usefully carry out a significant number of handovers were it on the neighbour list is not currently on the neighbour list for some reason or

- other. The reason might be the existing topology was imperfectly planned, or it might be that circumstances have changed since the topology was last determined. Many factors that influence the suitability of the current
- 5 topology can change, e.g. new buildings are built, new cells are added in the vicinity, subscriber usage levels and movement patterns change, and so on. Deletion of a cell from the current neighbour list is desirable when a cell is included in the current neighbour list of a given cell but in
- 10 practice is seldomly or never actually handed over to that given cell. Deletion of a cell is also desirable when handover to that cell degrades the overall system performance.
- 15 The prior art method of investigating and altering the topology is based on drive testing, which involves an operator literally driving around the coverage area of a cell in a vehicle. Drive routes, that is routes that are intended to be representative of the communications traffic contained
- 20 in the cell under investigation, are chosen. The drive-testing method involves driving the chosen routes making multiple telephone calls in both the mobile-to-land and the land-to-mobile directions. The duration of the calls should reflect the typical holding time of standard subscriber calls
- 25 for the particular drive route. The information from each call is recorded and post-processed. The drive test equipment is used to provide a breakdown of call successes and failures. It can also be used to highlight call quality. The recorded information is also processed to target poor
- 30 call success rates and poor call quality. In practice a team of

testers is required to carry out investigation of the topology of given cells for a particular region of a system.

- Drive-testing entails a number of significant disadvantages.
- 5    Complicated equipment is required by each team of drive-testers. In addition GPS position locating equipment is required for any subsequent analysis of the data since this fundamentally requires position information. Moreover the whole procedure is labour intensive and time-consuming.
  - 10   Being time-consuming not only involves direct cost implications but also has the disadvantage that the accuracy of the results achieved can be affected by changes during the time required for the testing and also it places restrictions on the network operator who cannot make
  - 15   changes to the system topology or other parameters during the period of drive-testing.
- 
- 20   Another disadvantage is that detailed local knowledge is required to choose realistic drive routes. Moreover, how ever well chosen, such routes are merely representative of real usage in the cell, and no correlation is made between the chosen drive-test routes and real subscriber usage
  - 25   patterns.
- 
- Yet another disadvantage is that drive-testing, as conventionally carried out in a vehicle, does not provide adequate correlation with respect to subscriber usage in
- 30   which the subscribers move on foot, which usage is

increasing with the use of hand-portable mobiles, in particularly within the office environment.

- Thus it would be advantageous to overcome the above disadvantages of drive-testing and provide an improved method of investigating and altering a topology of a cellular communication system.

### Summary of the Invention

10

The present invention provides a method of investigating a topology of a cellular communication system in which system one or more mobile stations assigned to a serving cell acquires identity data related to identities of a plurality of cells other than said serving cell, said system comprising a current neighbour list comprising an identity of one or more cells which are allocated as candidate handover cells in a current topology of the system; the method comprising the steps of:

15

- 20 a) collecting at least some of said identity data to provide collected data;  
b) determining, at least in part from said collected data, the identity of a first said other cell; and  
c) comparing the identity of said first said other cell with  
25 the cell identities of the current neighbour list.

The present invention also provides a method of altering a topology of a cellular communication system in which system one or more mobile stations assigned to a serving cell acquires identity data related to identities of a plurality

30



- of cells other than said serving cell, said system comprising a current neighbour list comprising an identity of one or more cells which are allocated as candidate handover cells in a current topology of the system;
- 5 the method comprising the steps of:
- a) collecting at least some of said identity data to provide collected data;
  - b) determining, at least in part from said collected data, the identity of a first said other cell;
  - 10 c) comparing the identity of said first said other cell with the cell identities of the current neighbour list; and
  - d) altering the current neighbour list responsive to said comparison step c).
- 15 Advantageous embodiments of the invention are as detailed in the dependent claims.

The methods according to the present invention achieve the advantage that investigation and alteration of the topology

20 is carried out without the need for drive-testing, thus overcoming the labour intensive and time-consuming disadvantages of drive-testing. The present invention achieves assessment of position dependent and moving factors without requiring to actually be on the move and

25 locate positions, as is the case with drive-testing. Thus position location equipment is not required. Yet another advantage is that the results achieved are more fully representative of the actual subscriber usage in a cell, thus overcoming the disadvantage of drive-testing that the

30 drive-test routes are only partially representative of real

usage and are also dependent on local knowledge for their planning. In this respect the present invention also has the advantage that the results achieved take full account of the usage of subscribers moving on foot.

5

### Brief Description of the Drawings

FIG. 1 is an illustration of a typical cellular communication system that may be used with the present invention.

10 FIG. 2 shows a representation of a neighbour list.

FIG. 3 is a flow diagram outlining the method of a preferred embodiment of the present invention.

### Description of Preferred Embodiments of the Invention

15

A first preferred embodiment relates to a cellular communication system which is GSM system, although it will be appreciated that the invention is not limited to such a system and could equally be used in other time division multiple access (TDMA) systems, in code division multiple access (CDMA) systems, or other cellular communication systems including combined TDMA/CDMA systems.

FIG. 1 illustrates a typical cellular communication system 25 10 having a coverage area formed by a number of cells 12-22. A conventional schematic representation showing a hexagonal cell pattern has been used to depict the cell areas, but in practice the shape and size of each cell will be different. In each cell, often at the centre, there is located 30 a base station (BS) 24-34 which controls communications

traffic 36, 38, 40 in its cell in accordance with procedures known to one skilled in the art. Each base station 24 - 34 may receive 38 and transmit 40 signals from/to mobile stations (MS) 42 - 46 that move throughout the communication system 10. In the preferred embodiment each of base stations 24, 26, 28 and 30 is coupled to mobile services switching centre (MSC) 50 through one base station controller (BSC) 47 and each of base stations 32 and 34 is coupled to MSC 50 through another BSC 48. An operations and maintenance centre (OMC) 49 is also coupled to MSC 50. Subject to the size of the communications system, OMC 49 may be responsible for the whole system or alternatively there may be a number of OMCs provided on a regional basis. MSC 50 is coupled to a public switched telephone network (PSTN) 51.

MS44 is assigned to BS28 as its serving cell by means of the following procedure. When MS 44 is switched on, it scans, by processes well known in the art, in an attempt to receive signals from base stations. In this scanning stage the MS scans using all the frequencies of the system. MS 44 receives signals from BS 28 and, in this example BSs 24, 26, 30 32 and 34. The MS determines which received signal is of the greatest strength, and then communicates to the corresponding BS, in the present case BS28, that it wishes to be connected to the system. BS28 undertakes a dialogue with MS44 to establish a communication path, and also at this stage interrogates the MS 44 to ascertain details from it including its identity. The identity of MS 44 and other details, such as cryptographic information, are transmitted

by the BS to the BSC 47, and on to the MSC 50. The MSC 50 stores these details so that when the mobile station is paged it can route the call from the PSTN 51 via the MSC 50 to BSC 47, and on to BS28, where communication between  
5 MS 44 and the system occurs. At this stage of the assignment procedure MS 44 becomes under the control of BS28. Control information is transmitted from BS28 to MS44. This control information includes inter-alia a control message indicating which sub-set of frequencies should be  
10 scanned from now on. The frequencies of the sub-set correspond to the frequencies employed by the BSs on the current neighbour list of BS28. The current neighbour list is explained more fully below. In addition, in the present embodiment, the control information includes an  
15 instruction that MS 44 should also scan some of the other frequencies used in the system. In the communication system, certain frequencies, i.e. frequency channels, may be dedicated to carrying control messages and certain other frequencies, i.e. frequency channels, may be dedicated to  
20 carrying communication traffic. One choice of which other frequencies are to be scanned is that of choosing to instruct the mobile station to scan all the frequencies that are used for control messages in the system, as opposed to the frequencies that are used for communication traffic. The  
25 outcome of the assignment procedure is that MS44 is assigned to BS28 which is therefore termed its serving cell. Thereafter MS44 will communicate with BS28 in response to a page or on a periodic basis to confirm to BS28 that it is still operating normally.

30

MS 44 will remain assigned to BS28 as its serving cell until it is either turned off, or handed over to another cell in the vicinity. Handover to another cell involves the current neighbour list, which is now explained in detail.

5

In the system of the present embodiment it is necessary to allocate, for each BS, those specific other BSs that will serve as candidate handover BSs. The list of identities of allocated handover BSs, and hence allocated handover cells, is called the neighbour list. In the system according to the present embodiment the neighbour list is stored at the base station. However, in other systems it could alternatively be stored at the BSC, the OMC, or indeed even remotely. The candidate handover BSs in the present example of BS 28 are chosen from those located in close geographical proximity to the cell area of BS28, and in the absence of any other factors will be allocated on a simple basis of all those cells geographically surrounding it. It is noted however, that were other factors influential, such as geographical and construction features, e.g. obstructions, subscriber densities, subscriber movement patterns, and uneven sized or shaped cells, then it would be preferable to allocate cells on a less systematic basis. The resulting allocation arrangement of candidate handover relationships between the BSs (and hence cells) of the cellular communications system is termed the topology of the system. In the present embodiment each of the five cells shown schematically around cell 16 in FIG. 1, that is cells 12, 14, 18, 20 and 22 are present on the current neighbour list of BS 28. Moreover, in the present

embodiment, no further cells are in the current neighbour list. It is pointed out however that in general, in a given cellular communication system there will typically be a maximum number of cells that can be contained on the  
5 current neighbour list of a cell.

In the GSM system of the present embodiment each BS broadcasts on its control frequency continuously in the  
10 form of a broadcast control channel (BCCH). In the present GSM case the control channel frequency is in the form of the absolute radio frequency channel number (ARFCN). Encoded in the BCCH is a further BS identifier termed the BS identifier code (BSIC). The overall BCCH-ARFCN and BSIC  
15 combination thus forms identity data relating to the identity of the base station, i.e. identity data relating to the identity of the cell.

As previously mentioned, MS44 scans the frequencies  
20 determined by the control message from BS 28, i.e. the frequencies contained in the so-called scan list of BS28. By virtue of receiving the control frequency signals, MS44 determines a signal strength metric, that is a measure of the strength of the signal in the case of each received BCCH.  
25 It also decodes the BSIC. Thus MS44 which is assigned to BS28 as its serving cell acquires identity data and signal metric data in the form of three pieces of information from each BS, i.e. other cell, it has successfully scanned, namely the BSIC, the signal strength metric, and the respective  
30 control channel frequency. In the present GSM case the

control channel frequency is in the form of an ARFCN index. These three pieces of information are attached together in the form of a module of data. Respective modules of data determined from a plurality of different  
5 BSs, i.e. a plurality of cells other than the serving cell, are passed back to BS28. In the present GSM embodiment, MS44 ranks the modules of data on the basis of the signal strength metric, and transmits only the six highest ranked modules of data to BS28. These are transmitted to BS28 in  
10 the form of a measurement report. Such a measurement report is fully defined in ETSI GSM Specifications 4.08.

The case of handover due to signal strength considerations will now be considered. However, it will be appreciated that  
15 this represents just one of a number of possible reasons for handover which are well known in the art.

As MS44, which is assigned to and in communication with BS28, moves towards BS32, the relative level of the signal  
20 strength metric from adjoining BS32 will increase, whilst conversely the serving cell signal strength will decrease. This will be reflected in the appropriate parts of the measurement reports. Within BS28 the BCCH-ARFCN and BSIC combination is converted to a BS identity, in this case  
25 BS32. Such a conversion can only occur if the BCCH-ARFCN and BSIC combination and BS identity are contained in the neighbour list. FIG. 2 schematically shows a representation of a neighbour list, from which it can be seen how a BCCH-ARFCN and BSIC combination corresponds  
30 to a specific BS identity. The inclusion of BS 32 in the

current neighbour list of BS28 plays a role in the remainder of the handover process from BS28 to BS32 which is now described.

- 5 When the signal strength metric from BS32 exceeds that of BS28 (the serving cell) by more than the handover margin, which in this case is 6dB, then MS44 is instructed by BS28 or some other system element to become assigned to BS32 as its serving cell instead of BS28. This re-assignment
- 10 procedure involves changing frequency of transmission so that MS44 is on a frequency utilised by BS32. Also, in the present GSM embodiment the timeslot (TDMA frame position) is additionally specified. As in the original assignment procedure, during handover a scan list of
- 15 frequencies pertinent to BS32 is received by MS44. The measurement reports between MS44 and BS32 differ over those earlier ones between MS44 and BS28 in that the serving information now relates to BS32, whilst the other modules of information will not relate to all the same ones
- 20 that were present in the case of BS28. In the process of handing over, information is transmitted between BS28 and BS32 so that the receiving cell (BS32) knows that MS44 will now become under its control. Signalling information flows between BSCs 47 and 48 and then BS 28 and 32 via the
- 25 MSC, whilst any connection to the PSTN is transparent. The BS and BSC elements will update counter records to reflect that handover has occurred, and the records will subsequently be transmitted to OMC 49 for storage.



The method of this preferred embodiment is outlined in flow diagram form in FIG. 3. The data constituting the measurement reports transmitted from MS44 to BS28, which thus includes the identity data, is further  
5 transmitted from BS 28 to BSC 47, where it is collected to provide collected data. In the present embodiment the corresponding data from a plurality of other mobile stations assigned to BS28 is also transmitted to BS28 and further transmitted from BS 28 to BSC 47, but it is pointed out that  
10 the invention may nevertheless be usefully employed using the data from just one mobile station. It is noted that the data could according to other embodiments of this invention be collected at BS 28 itself, or alternatively at other network nodes. In the present embodiment the way  
15 in which the step of determining, at least in part from the collected data, the identity of the one or more of the cells other than the serving cell, and also the step of comparing the identity of the one or more of the cells other than the serving cell with the cell identities of the current neighbour  
20 list is carried out, is as follows. From the collected data the respective ARFCN-BCCH and BSIC combinations from the modules of information within each measurement report are separated and then compared against the list of such combinations held on the current neighbour list. This  
25 procedure is implemented by connecting a computer to the BSC and using routine computer methods well known in the art. An alternative means on implementing these procedures would be to use a computer or part of a computer integrated in the BSC or BS itself. Those identities  
30 and corresponding ARFCN-BCCH and BSIC combinations that

appear in the current neighbour list are isolated. This is also carried out by routine computer methods. Any cell identities and corresponding ARFCN-BCCH and BSIC combinations on the current neighbour list that are not in the list of isolated ARFCN-BCCH and BSIC combinations have thus not made any contribution to the assessment process for handover represented by the collected data. Such a cell can be considered to be inappropriately contained in the current neighbour list. Consequently as a means of improving the topology of the system, the topology of the system is altered by altering the current neighbour list by deleting this cell from the current neighbour list.

The above deletion procedure may then be repeated for another ARFCN-BCCH and BSIC combination, i.e. cell identity, on the current neighbour list that is not in the list of isolated ARFCN-BCCH and BSIC combinations, and so on.

In carrying out the present embodiment a statistical sampling procedure is employed. The identity data is in the form of modules of data and the statistical sampling procedure comprises sampling a selection of the modules of data. More particularly the modules of data are constituted by the GSM measurement reports which are subjected to a statistical sampling procedure. In other words not every measurement report need be fully processed. In the present embodiment many tens of thousand of measurement reports, are processed so that the topology calculations are carried out with a high degree of accuracy. This provides the advantage that the results are not biased

for example by a single long communication between MS44 and BS28, since instead results from a plurality of communications between MS44 and BS28 are used. Thus information across the whole of the coverage area of BS28, i.e. over the whole cell, can be provided. Also in the present embodiment, data from one or more other mobile stations 64 within the cell may also be collected, sampled and used in the calculations. By using data from a plurality of communications, the measurement report data can originate from users moving over the whole cell, due to the mobility of the mobile stations within the GSM system of the present embodiment. The same advantages can also be achieved in the case of any other mobile communication system. Sampling the measurement reports is implemented such that from the series of measurement reports being collected, one report is analysed, then a number are skipped, i.e. ignored, then the next measurement report is analysed, then a number are skipped, and so on. One advantageous way of implementing this is to select every  $n$ th measurement report where  $n$  is an integer. The sampling procedure creates a sub-set of the whole data set of statistics. This process allows more information to be processed for a given size of computer memory and processing capability. Furthermore, many measurement reports are similar, so by adopting a sampling procedure more variants of information modules within the measurement report can be listed with the given computer. Alternative statistical sampling approaches can be used in the present embodiment, and is chosen by the skilled person according to the prevalent patterns of data

and desired or available amount of processing capacity. For example, the data can be collected on a sampling basis and then all the collected data further processed, and this may include collecting from only some of the mobile stations in a cell.

The above preferred embodiment is hereinafter termed the first deletion embodiment. A second deletion embodiment is implemented in the same fashion as the first deletion embodiment, except as follows. An amount or rate of occurrences at which respective ARFCN-BCCH and BSIC combinations are present in the collected data is determined using routine computer methods well known in the art. Deletion from the neighbour list is performed for a cell identity corresponding to an ARFCN-BCCH and BSIC combination for which the amount or rate of occurrences fulfils a predetermined criteria. In the present embodiment a cell identity is deleted from the current neighbour list if its ARFCN-BCCH and BSIC combination fails to constitute at least 1% of the total ARFCN-BCCH and BSIC combinations forming the collected data.

In the above deletion embodiments, alteration of the topology includes the step of deleting a cell identity from the current neighbour list. In another preferred embodiment, hereinafter termed the first addition embodiment, alteration includes the step of adding a cell identity to the current neighbour list, rather than deletion. The first addition embodiment is now described, and where applicable, items and procedures mentioned relate directly

to those already mentioned in the above description of the deletion embodiments.

As already described above, during the assignment  
5 procedure MS 44 becomes under the control of BS28.  
Control information is transmitted from BS28 to MS44. This  
control information includes inter-alia a control message  
indicating which sub-set of frequencies should be scanned  
from now on. The frequencies of the sub-set correspond to  
10 the frequencies employed by the BSs on the current  
neighbour list of BS28. In addition, in the present  
embodiment, the control information includes an  
instruction that MS 44 should also scan some of the other  
frequencies used in the system. In the communication  
15 system certain frequencies, i.e. frequency channels, may be  
dedicated to carrying control messages and certain other  
frequencies, i.e. frequency channels, may be dedicated to  
carrying communication traffic. One choice of which other  
frequencies are to be scanned is that of choosing to instruct  
20 the mobile station to scan all the frequencies that are used  
for control messages in the system, as opposed to the  
frequencies that are used for communication traffic.

The first addition embodiment is employed when, on  
25 comparing the identity data related to the identities of a  
plurality of cells other than the serving cell, which in the  
present case consists of ARFCN-BCCH and BSIC  
combinations, to the neighbour list in BS28, a combination  
is found that has no cross reference to a BS identity, i.e. the  
30 ARFCN-BCCH and BSIC combination is not on the neighbour

list. That is, the identity data has come from one of the other frequencies selected to be scanned, as explained in the previous paragraph.

- 5 In the present addition embodiment, since the ARFCN-BCCH and BSIC combination was not on the neighbour list, the identity of the base station, i.e. cell, has not yet been determined. Thus in the present embodiment, the comparison step referred to as c) in the appended claims is carried out before the determination step referred to as b).
- 10 It is thus emphasised that the various steps can be carried out in different order according to the present invention, depending merely on when it is most convenient or economical to implement each step. In the present case, it is directly evident to the skilled person that it is not necessary to identify the cell under investigation until it has been decided whether to add it to the neighbour list. However, in other circumstances the skilled person may, for evident reasons, choose to identify the cell first. Similarly,
- 20 depending on the details of any particular system to which the present invention is applied, the skilled person may under the present invention elect to carry out two or more of the steps on an iterative basis, for example depending on the system it may be necessary or desirable to use an iterative process involving the determining step b) and the comparison step c).
- 25

Since the ARFCN-BCCH and BSIC combination corresponds to the identity of a cell identity that is not on the current neighbour list but is successfully received by the scanning

30

process, it represents a cell identity that could possibly have made a contribution to the assessment process for handover represented by the collected data had it in fact been on the neighbour list. Likewise it would be  
5 advantageous should that cell identity be included in the neighbour list in future. Consequently as a means of improving the topology of the system, the topology of the system is altered by altering the current neighbour list by adding this cell to the current neighbour list.

10

In the present first addition embodiment the identity of the cell corresponding to the ARFCN-BCCH and BSIC combination that it has been decided should be added to the current neighbour list is then determined, at least in  
15 part from the collected data. Thus, in this embodiment, determining step b) of the claims is carried out after comparing step c), the order of the steps in general being chosen by the skilled person as mentioned already above in the description of the present first addition embodiment.

20

In the present first addition embodiment, which relates to a GSM system, the determination of the identity of the cell is achieved by applying the assumption that the ARFCN-BCCH and BSIC combination is unique to a particular BS. If  
25 in certain circumstances this assumption proves to be imperfect, then supplementary information, for example the X and Y co-ordinates of each BS in the system, can be used. The distance between the serving BS and all other BSs is calculated, using trigonometric calculations well known to  
30 those in the art to provide a database having the ARFCN-

BCCH and BSIC combinations of different BSs in correspondence with their respective distances from the serving BS. This database is sorted according to ARFCN-BCCH and BSIC combination and in ascending distance from the serving BS. The database is searched to find those cells that have the candidate ARFCN-BCCH and BSIC combination and have an appropriate distance from the serving BS. The distance is appropriate to range and coverage of the serving cell and its surrounding neighbours. For example in a city cells a few kilometres away would be considered, whereas in country areas the neighbours may be at a greater distance. Further information in terms of the antenna orientation and the predicted signal strength in the serving cell's coverage area can be used to distinguish when two neighbouring cells have similar distances from the serving cell and the same ARFCN-BCCH and BSIC combination in a system.

In the addition embodiment mentioned above, after adding, or determining to add, a particular ARFCN-BCCH and BSIC combination to the current neighbour list, another ARFCN-BCCH and BSIC combination can then be processed.

As mentioned above the module of data acquired by MS44 includes a signal strength metric in addition to the BSIC and the respective control channel frequency. In a further embodiment, hereinafter termed the third deletion embodiment, this signal strength metric is additionally employed.

30



- The identities of the cells other than the serving cell are repeatedly ranked in ranking positions in a ranking order according to the respective signal strength metrics. That is, each module of information is ranked according to the
- 5 signal strength metric, where each module of information comprises an ARFCN-BCCH and BSIC combination and an attached signal strength metric value. In a GSM system the six cell identities with the highest ranked signal strength metrics are reported in the measurement report,
- 10 the six ranking positions being termed neighbour positions, in which neighbour position 1 represents the highest signal strength. For a particular cell identity, which in this embodiment is in the form of a particular ARFCN-BCCH and BSIC combination, the extent that this respective other cell
- 15 identity appears in the six respective ranking positions in the sampled data is then determined. This can be performed using an automated procedure using known computer methods.
- 20 In the present embodiment deletion is carried out for a particular ARFCN-BCCH and BSIC combination if it fulfils a predetermined criteria consisting of whether it appears only in a predetermined position or range of positions of the six ranking positions. In the present embodiment
- 25 deletion is carried out if the ARFCN-BCCH and BSIC combination has only appeared in positions 3 to 6. An alternative possibility is to carry out deletion if the ARFCN-BCCH and BSIC combination has only appeared in positions 4 to 6.

30

In the above described third deletion embodiment it is also possible to include in the predetermined criteria the earlier described function related to an amount or rate of occurrences at which respective identities of the other

5 ARFCN-BCCH and BSIC combinations, i.e. cells, are indicated in the collected identity data. For example the criteria can be that a particular ARFCN-BCCH and BSIC combination, i.e. cell identity, is deleted from the current neighbour list if it only appears in positions 4 to 6 and if the combination fails

10 to constitute at least 0.5% of the total ARFCN-BCCH and BSIC combinations forming the collected data.

In a further embodiment, hereinafter termed the second addition embodiment, the ranking positions described

15 above are employed. In this embodiment the six neighbour positions of the measurement report are allocated into three ranges consisting of neighbour position 1, neighbour positions 2 to 3, and neighbour positions 4 to 6. The predetermined criteria employed for addition of a cell

20 identity to the current neighbour list is a function of these three ranges. It will be appreciated that numerous possible functions of these ranges can be employed to advantageous effect, and that the exact choice will be made by the skilled person depending on the particular system requirements.

25 One example for the predetermined criteria can be that the particular ARFCN-BCCH and BSIC combination has been reported in neighbour position 1 in more than 10% of the measurement reports sampled or that the particular ARFCN-BCCH and BSIC combination has been reported in

the range consisting of neighbour positions 2 to 3 in more than 30% of the measurement reports sampled.

- 5 In all the embodiments described above, after deleting or adding, or determining to delete or add, a particular ARFCN-BCCH and BSIC combination from or to the current neighbour list, another ARFCN-BCCH and BSIC combination can then be processed.

10

**CLAIMS**

1. A method of investigating a topology of a cellular  
5 communication system in which system one or more  
mobile stations assigned to a serving cell  
acquires identity data related to identities of a plurality of  
cells other than said serving cell,  
said system comprising a current neighbour list comprising  
10 an identity of one or more cells which are allocated as  
candidate handover cells in a current topology of the  
system;  
the method comprising the steps of:  
a) collecting at least some of said identity data to provide  
15 collected data;  
b) determining, at least in part from said collected data, the  
identity of a first said other cell; and  
c) comparing the identity of said first said other cell with  
the cell identities of the current neighbour list.  
20
2. A method according to claim 1 wherein said steps a) -  
c) are performed for a plurality of said other cells.
3. A method according to claim 1 wherein said steps a) -  
25 c) are performed for a plurality of mobile stations  
assigned to said serving cell.
4. A method according to claim 1 wherein one or more  
of steps a), b) and c) is performed according to a statistical  
30 sampling procedure.

5. A method according to claim 4 wherein said identity data is in the form of modules of data and said statistical sampling procedure comprises sampling a selection of said  
5 modules of data.

6. A method according to claim 5 wherein said system is a GSM system, said modules of data are measurement reports, and said selection comprises selecting every  $n$ th  
10 measurement report where  $n$  is an integer.

7. A method according to claim 1 wherein said identity data is acquired by said one or more mobile stations by scanning said other cells and/or said serving cell.  
15

8. A method of altering a topology of a cellular communication system in which system one or more mobile stations assigned to a serving cell acquires identity data related to identities of a plurality of  
20 cells other than said serving cell, said system comprising a current neighbour list comprising an identity of one or more cells which are allocated as candidate handover cells in a current topology of the system; the method comprising the steps of:  
25 a) collecting at least some of said identity data to provide collected data;  
b) determining, at least in part from said collected data, the identity of a first said other cell;  
c) comparing the identity of said first said other cell with  
30 the cell identities of the current neighbour list; and

d) altering the current neighbour list responsive to said step c).

5 9. A method according to claim 8 wherein said steps a) - c) are performed for a plurality of said other cells.

10 10. A method according to claim 8 wherein said steps a) - c) are performed for a plurality of mobile stations assigned to said serving cell.

11. A method according to claim 8 wherein one or more of steps a), b) and c) is performed according to a statistical sampling procedure.

15 12. A method according to claim 11 wherein said identity data is in the form of modules of data and said statistical sampling procedure comprises sampling a selection of said modules of data.

20 13. A method according to claim 12 wherein said system is a GSM system, said modules of data are measurement reports, and said selection comprises selecting every  $n$ th measurement report where  $n$  is an integer.

25 14. A method according to claim 8 wherein said identity data is acquired by said one or more mobile stations by scanning said other cells and/or said serving cell.

15. A method according to claim 8 or 9 wherein said step d) comprises deleting from the current neighbour list the identity of a said other cell which is in the current neighbour list and which is not included in those identity or  
5 identities determined by said step b).

16. A method according to claim 9 further comprising determining an amount or rate of occurrences at which respective identities of said other cells are indicated in said  
10 collected data; and wherein said step d) comprises deleting from the current neighbour list the identity of a said other cell for which said amount or rate of occurrences fulfils a predetermined criteria.

17. A method according to claim 9 wherein identities of said other cells are repeatedly ranked in ranking positions in a ranking order according to a signal metric, thus providing ranking data, and said step d) is performed responsive to a predetermined criteria which includes a  
20 function relating to what extent a respective other cell identity appears in a predetermined position or range of positions within said ranking order.

18. A method according to claim 17 wherein said  
25 predetermined criteria is that a said other cell appears only in a predetermined position or range of positions within said ranking order and said step d) comprises deleting from the current neighbour list a said other cell identity.

30

19. A method according to claim 18 wherein said ranking positions are six neighbour positions in a measurement report of a GSM system and said predetermined range of positions is either positions 3 to 6 or positions 4 to 6.

5

20. A method according to claim 17 wherein said predetermined criteria also includes a function related to an amount or rate of occurrences at which respective identities of said other cells are indicated in said collected data.

10

21. A method according to claim 8 or 9 wherein said step d) comprises adding to the current neighbour list the identity of a said other cell which is not in the current neighbour list and which is included in those identity or identities determined by said step b).

15

22. A method according to claim 17 wherein said ranking positions are six neighbour positions in a measurement report of a GSM system; said function of said predetermined criteria includes allocation of said six neighbour positions into three ranges consisting of neighbour position 1, neighbour positions 2 to 3, and neighbour positions 4 to 6 respectively; and said step d) comprises adding to the current neighbour list the identity of a said other cell which is not in the current neighbour list.

20

25

23. A method of investigating a topology of a cellular communication system substantially as hereinbefore

30



described and with reference to the accompanying drawings.

24. A method of altering a topology of a cellular  
5 communication system substantially as hereinbefore  
described and with reference to the accompanying  
drawings.



The  
Patent  
Office

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Application No: GB 9724888.4  
Claims searched: All

Examiner: Gareth Griffiths  
Date of search: 8 April 1998

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): H4L (LDSHE, LDSHS, LDSHX)

Int Cl (Ed.6):

Other: Online Database: WPI

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
X	WO97/32445 A1 (ERICSSON) p.15 line 26 - p.29 line 1	1 & 8 at least
X	WO9706648 A1 (ERICSSON) p.14 line 18 - p.27 line 26	1 & 8 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

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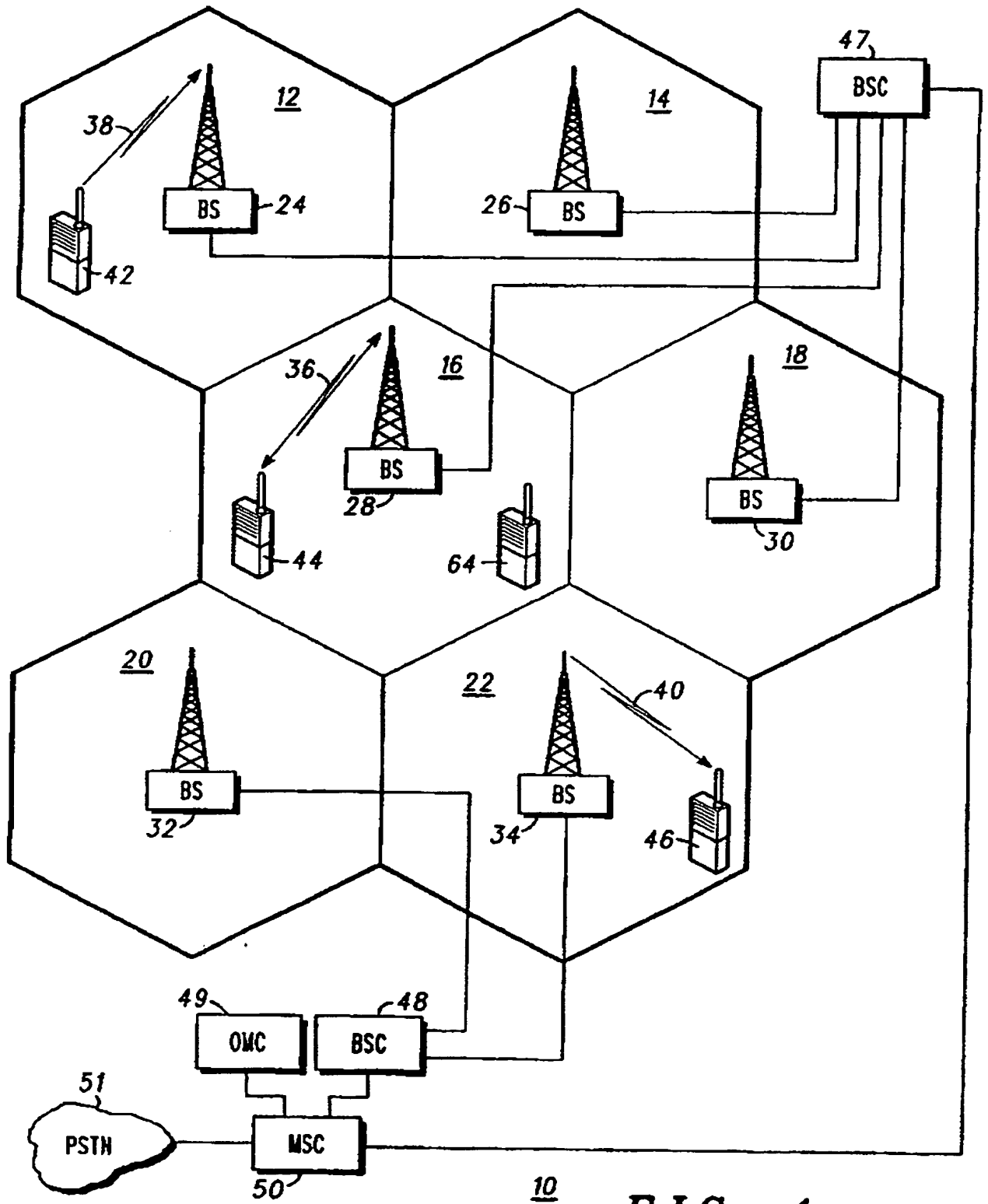


FIG. 1

LIST No.	BCCH- ARFCN	BSIC
1	10	6
2	14	3
3	12	5
⋮	⋮	⋮
32	20	16

FIG. 2

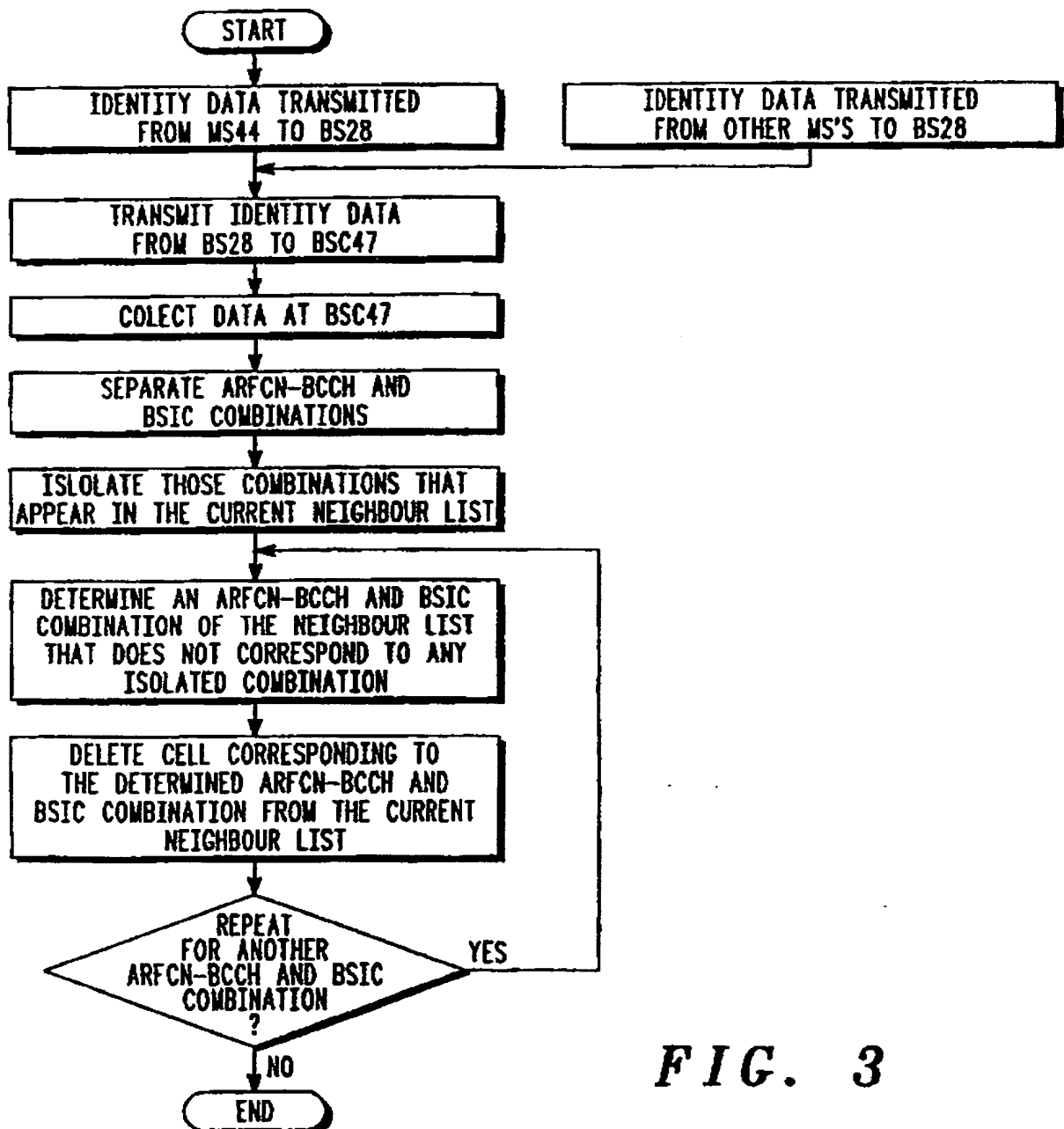


FIG. 3